Lower Limit on Radius as a Function of Mass for Neutron Stars [1]

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Tentative limits on mass and radius deduced from models of quasi periodic oscillations in X-ray brightness (QPOs) of neutron stars in low-mass binaries have been employed recently to discriminate among models of the equation of state of dense nuclear matter. The X-ray pulsar, Sax J1808.4-3658, is a particularly interesting object; it produces coherent X-ray emission with a 2.5 ms period as well as X-ray bursts. Based on an analysis of radiation from this object, a limiting mass-radius relationship was derived which is difficult to reconcile with existing neutron star models [2]. The mass-radius relationship derived would be consistent with an interpretation of Sax J1808.4 as a strange star candidate as found by the above authors.

Against this background our purpose is to derive a model-independent mass-radius constraint for neutron stars that depends only on minimal and well accepted principles. The limiting relation is analogous to a previously obtained lower limit on the Kepler period of a rotating star as a function of its mass [3, 4].

The most conservative minimal principles and constraints are: 1. Einstein's General Relativity is true. 2. The matter of the star satisfies $dp/d\rho \geq 0$ which is a necessary condition that a body is stable, (Le Chatelier's principle). 3. The equation of state satisfies the causal constraint; a sound signal cannot propagate faster than the speed of light, $v(\epsilon) \equiv \sqrt{dp/d\epsilon} \leq 1$. 4. The high-density equation of state matches continuously in energy and pressure to the low-density equation of state of [5] and has no bound state at any density.

Figure 1 illustrates the limit obtained for the 2.5 ms X-ray pulsar, Sax J1808.4, by Li et al. (1999), together with the limit obtained in our model independent way. Neutron stars must lie to the right of our limit and the X-ray object must lie on or to the left of the line so marked. Li et al. (1999) have proposed the object as a strange-star candidate. However, from our model independent constraint, it is clear that neutron stars cannot be ruled out, even if many explicit models can, always provided the X-ray phenomena are modeled correctly.

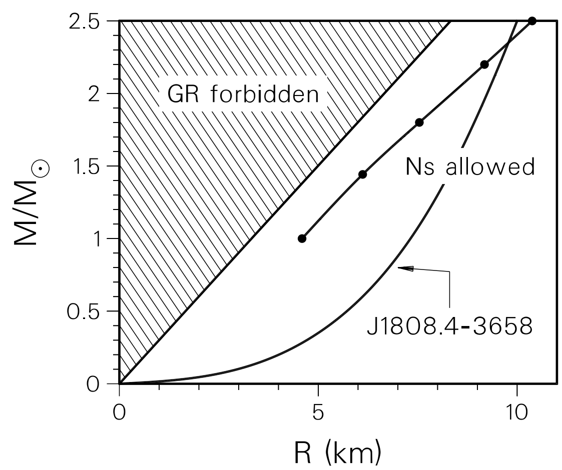

Figure 1: According to the QPO model of [2] the X-ray star must lie on or to the left of the curved line $R \propto M^3$ and by our model independent determination, neutron stars must lie to the right of the line marked 'Ns allowed'.

References

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